The Advent of Radar in The Royal Australian Navy

George Stevens

The information contained in this article, and for those intended for publication in a later issue of the *Journal of Australian Naval History*, has been contributed, in the main, by those ex-RAN personnel who were closely involved in the development, manufacture, repair, and use of this then highly secret technology during the years of World War Two and immediately afterwards. Where necessary, this has been confirmed and supplemented by reference to official archives and reputable monographs.

Introduction

The concept of radar had been enunciated by the German physicist Heinrich Hertz in 1888, and it was demonstrated in Germany in 1904 by Christian Hulsemeyer with his patented 'Telemobiloscop'.[1] However, nothing was done then to develop the concept, because the technology to do so did not exist. During the 1920s and 1930s the use of wireless telegraphy and wireless telephony grew dramatically, largely due to the invention and use of the thermionic valve and its derivatives. These devices made possible the generation of frequencies up to 25 Megahertz (MHz), which is at the very low end of the frequency spectrum suitable for use in microwave [1]radar transmissions. Impending European hostilities during the 1930s added urgency to the development of the concept into a workable device, which could provide a decided military advantage to its possessors. By the mid 1930s, after a gestation period of some 50 years, radar was at last becoming a reality, but the technology then, compared with the mature product we now see, after a further 50 years of development, was quite Stone Age.

Although various experimental models of radar sets had been produced since 1935, possibly the first successfully deployed system was the UK-developed 'Chain Home' Radio Location network, which commenced secret operations in July 1937. Successful trials subsequently led to the establishment of twenty Radio Direction Finding (RDF – the initial British acronym for radar) stations across southern England.[2] Because of the limitations of the vacuum tube technology it employed, the Chain Home radar operated at a frequency of 25 MHz, a wavelength of 12 metres, which gave a detection range of a medium bomber of ranges in excess of 40 miles. It was only in 1939 that the British discovered the resonant cavity magnetron ~~resonator~~, which could produce high power pulses at a frequency of 10~~,000~~ G~~M~~Hz[2], with a much shorter wavelength of 3 centimetres.

When this device entered production in 1941, radars using it gave a far more accurate definition of range and bearing of a target than that of a longer wavelength pulse[3]. The magnetron, when used as the transmitter in conjunction

[1] ~~Note that there is a lot of research into HF radar these days that make use of the 2-30MHz range. "Microwave" on the other hand is in the order of GHz as you know.~~

[2] ~~I think it is more typical to speak of microwave frequencies in GHz not MHz.~~

[3] ~~There are a few factors here. A high power radar is able to transmit sufficient energy for detection using a short pulse width. It is this short pulse width that gives the radar its range resolution and accuracy. The fact that these radars were pushing into the microwave region meant that a reasonable size antenna had much~~

with the US-developed klystron local oscillator, was a quantum leap forward in radar technology, and placed the Allied military far ahead of its Axis opponents in the science of radar assisted weaponry. This is not to suggest that the Germans, in particular, lagged at all. The German pocket battleships were fitted with the *Dt-geraet* gunnery radar in 1939, also useful in surface search out to 18.5 nm, which was somewhat in advance of British designs. [3]
There are a few factors here. A high power radar is able to transmit sufficient energy for detection using a short pulse width. It is this short pulse width that gives the radar its range resolution and accuracy. The fact that these radars were pushing into the microwave region meant that a reasonable size antenna had much better gain (helping with detection range) and was very directional (resulting in angular resolution and accuracy). So the resonant cavity magnetron gave radar a few real kicks in performance.

In reading the examples which follow, this point of the primitive state of the art should be kept in mind. All design calculations were done by the design teams using standard mathematical formulae, pen, paper and active brain power. A high level of secrecy was essential, which militated against open communication of new ideas. Most component devices, spares and repair parts had to be hand made to order. In the ships in which radar was fitted, an Avometer, soldering iron, a few spare 'tubes' and lots of trial and error were the standard tool kit for the maintenance mechanics.

In combat zones under darkened ship conditions, it was common for operational and maintenance work to be done in restricted light in a close and confined cabin, with ambient temperatures of 40 degrees Celsius plus, with the unfortunate personnel occasionally retching into a bucket as the ship rolled and pitched in heavy seas. Circuit diagrams and maintenance manuals were shipped anything up to six months after the equipment had been commissioned. Yet despite all these barriers, by November 1942 the Royal Australian Navy (RAN) had a powerful pantry of radar equipment, and the innovative human skills to allow radar's effective use in many different circumstances, as the stories which follow illustrate.

Radar Basics

For most of those reading these radar and related articles, the concept of the technology will be familiar. However, a short refresher course to explain some of the principles which led to early radar design would be appropriate.

Radar employs electromagnetic waves, which have a ~~velocity~~ speed of approximately 300,000 kilometres[4] ~~million metres~~ per second. The method of measuring the distance between the transmitter and an object from which the transmitted energy has been reflected is to multiply the ~~velocity~~ speed of the electromagnetic waves by half the time elapsed from the transmission to reception of the echo, as the energy has had to travel twice the distance, as shown:

$$R = \frac{c \times T}{2}$$

~~better gain (helping with detection range) and was very directional (resulting in angular resolution and accuracy). So the resonant cavity magnetron gave radar a few real kicks in performance.~~ Not ~~sure if you want to add this sort of detail.~~

[4] Velocity is a vector having both magnitude and direction. Speed simply has magnitude. I have found people are better able to understand the speed of light (if that's possible) when expressed as km/s not m/s. Personal preference.

where R is the range to the target in metres, c is the speed of light (3×10^8 m/s), T is the time taken for the radar energy to travel to the target and return in seconds.[5]

For example~~. To illustrate,~~ if a pulse of electromagnetic energy is transmitted and the returned echo comes in 50 microseconds, we work out the range to the target as follows:

$$R = \frac{c \times T}{2}$$
$$= \frac{3\times10^8 \times 50 \times 10^{-6}}{2}$$
$$= 7.5\,\text{km}$$

~~the formula is d = 3 x 10 to the power of 8, x 50 times 10 to the power of minus 6 =15,000 ÷ 2 = 7.5 Km. The target is 7.5 Km away from the transmitter.~~

If the target has radial velocity relative to the transmitter, then the returned echo exhibits Doppler Effect – a small shift in the received frequency from that transmitted. As an example, at an operating frequency of 10 GHz (10,000 MHz or 3 centimetre wavelength) a radial velocity of 1 nautical mile (1.883 kilometres[6]) per hour provides a Doppler frequency shift of 34 Hz. It should be noted however that the Doppler Effect occurs only when there is a radial difference between the Radar set and the target. If both the Radar set and the target are travelling in a straight line at the same speed, Doppler Effect will be zero, because the relative distance separation remains constant. As well, if the target is moving in a circular path of constant radius about the Radar set, again there will be no frequency change, thus no Doppler Effect.

Maxwell ~~(I think?)~~ discovered that the product of frequency and wavelength of electromagnetic energy is equal to its speed. Given that the speed of propagation is approximated by the speed of light, this discovery gives the following important relationship:

$$c = f \times \lambda$$

where c is the speed of light (3×10^8 m/s), f is the frequency of the electromagnetic energy in hertz, and λ is the wavelength of the electromagnetic energy in metres.

Given that the speed of light is a constant, this expression allows us to determine the operating wavelength of a radar system provided we know its operating frequency. For example, a radar operating at 1 GHz has the following wavelength:

$$c = f \times \lambda$$
$$\text{or}$$
$$\lambda = \frac{c}{f}$$
$$= \frac{3\times10^8}{1\times10^9}$$
$$= 0.3\,\text{m}$$

~~The relationship between frequency, wavelength and velocity is constant, where wavelength = velocity ÷ frequency. As an example, a wavelength of 30~~

[5] ~~Again up to you, but I think simple arithmetic like this is better shown as a formula then in words.~~

[6] ~~You would be better placed than me here but I thought a nautical mile was 1.852 km.~~

~~centimetres will be derived from a velocity of 3 x 10 to the power of 8 ÷ by 1,000 MHz (1,000 X 10 to the power of 6.)~~

Again for the benefit of those not familiar with Radar, following are brief explanations of some of the words and terms used in these articles:

'A' scan	This is a single line horizontal trace on a cathode ray oscilloscope (CRO). At the left hand end, the large vertical pulse indicates the initial transmission signal. To the right along the trace, a returned echo is shown as another smaller vertical pulse. The horizontal (or "x" direction) indicates range or time, and the vertical (or "y" direction) indicates amplitude.
Klystron	Using the superhetrodyne principle of radio reception (see explanation of this), the klystron was used initially as a local oscillator. As the technology developed, more powerful klystrons were developed and used as transmitters.
Lantern	Imagine an old fashioned cylindrically shaped lantern, but much larger. In this on the mast would be housed the Radar antenna, and in some cases much of the transmitting and receiving equipment.
Magnetron	This was one of the main transmitters. It could produce electromagnetic signals at frequencies between 10,000 and 3,000 MHz, for pulse durations of less than 1 microsecond, at pulse repetition rates of hundreds per second and with peak power outputs of hundreds of watts.
Modulator	This is simply the device which regulates the frequency, and sometimes the duration of, the radar transmission pulses
PPI	Plan Position Indicator. A modified CRO, with the source radar (in our case, the ship) being at the centre of the circle and the ship's heading usually shown as bearing 000. As the radar transmitter pulsed, a trace is projected on the screen from the centre to the periphery. A returned echo is seen as a bright spot on the trace. As the antenna rotated, the PPI trace rotated in synchronism. Variations of this allow the presentation of slant range of aircraft echoes. Thus range, azimuth and altitude of aircraft can be quickly determined.
PRF	Pulse repetition frequency, or the number of transmitted pulses each second. These vary between radars, but a PRF of 500 was typical. The higher the PRF the more information can be obtained from the returned energy but range ambiguity can become an issue if PRF is increased too much,
Sector sweep	Instead of a 360 degree continuous rotation, some radar models were designed to allow backwards and forwards sweeps of a selected sector, e.g. 20 degrees both sides of ship's head
Superhetrodyne principle	Amplification of electromagnetic signals is made more reliable by mixing the desired signal with one at a slightly different frequency, and by selecting the resultant difference. Thus the reflected echo signal of a magnetron transmission at 10,000 MHz could be mixed with a klystron-generated local signal of, say, 10,009 MHz. There would be four resultant signals i.e. the original two, the sum (20,009 MHz) and the difference

	(9 MHz). Selection of the 9 MHz for further amplification would produce the best frequency to be used to create the displayed echo signal.
Thermionic valve	The principle of operation was that a ——stream of electrons was emitted from the heated cathode, and the quantity of these electrons varied by an electric signal applied to a grid, placed physically between the cathode and the anode. In this process, the amplitude of the signal coming in to the grid would appear greatly magnified when seen at the anode. There were many variations of this device. The distance which the electrons had to travel from cathode to anode was a factor which determined the frequency limits of the valve in question.
Thyratron	This was a high power mercury vapour triode used as a pulse modulator for transmitters
Wave guide	Waveguide is usually a [7]rectangular section metal tubing, sometimes gold-lined. UHF and higher radio signals carry much more effectively along the inside of waveguide material. The length of the waveguide can be many metres without significant loss of performance although ~~waveguide loss is a function of waveguide length.~~ The dimensions of the cross section must relate to the frequency of the transmitted signal. A 3 cm transmission uses 3 cm cross section waveguide for example~~.~~ the limitation on waveguide is that its larger dimension (in the case of a rectangle) must be greater than half a wavelength and the smaller dimension should be around a quarter wavelength. [8]
Wave guide horn	At the radar antenna, the transmission signal leaves the waveguide and is directed to the antenna via an aperture or horn. For example, if the antenna is a parabolic reflector, the horn is located at the focal point, which may be up to 50 centimetres from the nearest point of the surface of the reflector.
Yagi array	An antenna array named after its Japanese inventor. Essentially a straight rod pointing away from the ship's mast in horizontal along which are one active element and a number of reflector and director elements, cut to different lengths. The net result is a highly directional antenna. Yagi arrays are commonly used in domestic free-to-air television antennas

Early Days

In 1935, the Royal Navy's (RN) most advanced method of detecting distant objects such as enemy ships and aircraft was seven power binoculars. Four years later at the outbreak of World War Two, the new technology known to the British as RDF (and in the USA as Radio Echo Equipment), was capable of detecting an aircraft up to 60 nautical miles distant. Later, the Allied forces used the common

[7] There are also other shapes commonly used such as circular and square.

[8] ~~This is not really correct.~~ tTh~~h~~e limitation on waveguide is that its larger dimension (in the case of a rectangle) must be greater than half a wavelength and the smaller dimension should be around a quarter wavelength.

terminology of Radio Detection and Ranging, which became better known by its acronym RADAR.

Radar was not invented. It was a progressive development of concepts in the UK, the USA, Germany, Japan, France and Italy over a period of perhaps thirty years. These developments focussed on the four main components of a radar system, namely a radio transmitter with a pulse generator, an aerial array to send and to receive the electromagnetic pulses, a receiver to amplify and interpret the echo pulses, and an indicator, such as a cathode ray oscilloscope, on which to display the results for human interpretation.

In the early part of the 20th century, knowledge of developments in different countries was shared. A prime example is the Japanese-developed Yagi directional aerial (see Terms above). However, it became apparent that the knowledge being accumulated could be of vital security importance, and a veil of secrecy spread over the whole process in all of the technologically advanced countries from early 1930 onwards.

In February 1935 during British experiments, an aircraft was detected at a range of eight miles as it was flying within the beam of the British Broadcasting Commission's 50 metre short wave station at Daventry. Recognising the requirement to create high powered transmitters operating in the ultra shortwave spectrum, British experimental work resulted in laboratory models of a device which operated at 50 centimetres, and a magnetron valve capable of working at 36 centimetres. However, at this stage, these were a long way from being incorporated in operational equipment.

The RN fundamental operational concept was that radar should be used for early warning, and that the conventional range finding process of an optical range finder would then be used to track and engage the target. To this end, the stated RN requirement was to have radar which would give early warning of aircraft at sixty[9] miles and ships at ten miles. A further requirement was that the radar would provide precise location of aircraft at ten miles and of ships at five miles.[4] The RN required short wave equipment, because longer wave transmitters and receivers meant longer and bigger aerial systems which, while achievable on land, were impractical in a ship. So the RN development focus was on equipment operating in the S, C and X bands, that is wavelengths between 3 and 30 centimetres.

The first British operational seaborne radar was the Type 79, which was first fitted in the battleship *Rodney* and the cruiser *Sheffield* in early 1938. Trials conducted in *Sheffield* recorded detections of aircraft thirty nautical miles distant at 3,000 feet [910m], forty-eight miles distant at 7,000 feet [2135m] and fifty-three miles distant at 10,000 feet [3050m] .[5] By May 1939, more efficient transmitting valves improved these figures by an average of 33 per cent. However, as shorter wavelength equipment was still very much in the development stage, the RN had to be content with the Type 79 until 1940, when the Type 281was introduced, followed by the Type 271 in 1941. The 271 was a surface warning set, with a cylindrical parabolic antenna. Its performance varied according to the antenna's height above sea level, but in a sloop or corvette, 1942 trials gave fairly unimpressive ranges of 3 miles on a surfaced submarine, six miles on a destroyer, eight on a cruiser or ten on a battleship. These were all within effective ranges of the targets' weapons systems, so 'warning' was something of an overstatement. [6]During this intervening period, the Type 79

[9] You should be consistent with your conventions. Either use numerals or words to describe quantities. I would recommend numerals. For example, rather than sixty miles, I would say 60 miles. This occurs throughout the paper.

underwent a number of modifications, improving its range, power output, and general capability.

Although the UK had an operational RDF system in 1937, it wasn't until early 1939 that Australia took an active interest in this secret technology. Throughout all of 1939, there was much highly secret correspondence between such luminaries as Australia's High Commissioner to UK, Stanley Bruce, the two Prime Ministers, Joseph Lyons (who died in 1939) and Robert G. Menzies, Australian Cabinet ministers, senior officers of Australia's armed forces, and members of Australia's Radiophysics Board. A key person in this latter organisation was Dr. D.F. Martyn, DSc, PhD, ARCSc, FRMetS, FInstP, who was sent to UK to investigate and to report.[7] In March 1939, Dr. Martyn sent a telegram to Lyons recommending that some of the British radar equipment should be purchased. The Prime Minister immediately authorised an order to be placed, and one of the first recipients of the equipment was to have been HMS *Amphion*, destined to become HMAS *Perth*. Unfortunately, a grave shortage of radar sets meant that the RN had none to spare, and the RAN's hopes of having one radar-equipped cruiser in 1939 were dashed.[8]

However, following Dr. Martyn's UK visit, a top level Australian government committee was formed to evaluate aspects of this new technology, Radio Location. The committee decided that a Radiophysics Laboratory should be established in the grounds of the University of Sydney. A further decision was that Australia should develop equipment as an alternative to relying on UK production and availability.[9] These recommendations were fully supported by the Australian Government, and steps were taken to implement the establishment of the required procedures. In broad terms, the Radiophysics Laboratory became responsible for the design and development of prototype equipment, for the training of senior personnel of the armed services, and their respective support functions, and in providing training in the various scientific aspects of the operation of the equipment. The Post Master General's Department became responsible for advising the Radiophysics Board on the types of equipment required, and for the installation, operation and maintenance of the equipment.[10]

The laws of supply and demand - being no different for Radio Location than for any other commodity - coupled with Britain's preoccupation with the war in Europe, meant that availability of equipment for the Australian armed forces was extremely limited. This promoted the need for a degree of self sufficiency for Australia, and Australian industry was also called upon to provide radar equipment for the British China and Eastern Fleets.[11] To this end, contracts were let to Amalgamated Wireless Australia (AWA) for the manufacture of units of Radio Location models for the three services, which soon became known as 'radar'. [12]

One of the first sets produced for the RAN was the Type A272, intended to give surface warning of submarines and other small craft. It had a 10cm wavelength, a relatively low power, and was credited with a maximum range of 25 nm. The first equipment underwent sea trials in HMAS *Kybra* in November 1942.[13] The antenna consisted of two 'cheeses' mounted one above the other: the lower transmitted, the upper received. The cheeses were about 1.25m across the horns, and the whole antenna stood about 1.5m. It was contained in a distinctive plywood 'lantern', approximately 2.5m in diameter and 2.75m high. ~~The antenna was mounted~~ .....[10] A~~A~~ccess to the antenna ~~itself~~ was via a removable plate in the lantern base.[14]

In May 1944, an upgraded version of the A272 - the A276 – was trialled at sea in HMAS *Yandra*.[15] Pre-war, *Yandra* and *Kybra* were small coastal steamers. Both were requisitioned by the RAN, fitted with a 4 inch gun, port & starboard

[10] Incomplete sentence.

antiaircraft guns, and depth charge racks aft. From 1942 on however, their prime role was as training vessels for radar operators, and for this they were equipped with British Type A286 forward and aft, the Australian A272 forward and aft, and A271 aft. The A271 was replaced by type A276. As well, a British Type 79 was fitted for the purpose of providing performance assessment for the radar maintenance personnel.

In mid 1942, Lieutenant Commander Cree was sent by Navy office on a tour of the UK and USA seeking information on the radar equipment, radar countermeasures and electronic navigation aids coming into service in the USN and RN. On his return he filed an extensive report in which a number of observations and suggestions were made. It was clear that major advances in reducing the size and weight or radars and their antennas and in radar performance were being made on both sides of the Atlantic, with gunnery radar range discriminations now down to tens of metres and ranges for these high definition sets out to 20nm. The Americans were noted as being very interested in radar prediction for light AA guns – a big deficiency in British weapons. Cree proposed, and the Naval Board accepted, a policy that the radar outfits of RAN ships should conform, as far as practicable with those of their RN equivalent classes. [16]

The products of indigenous research and manufacture were augmented by British equipment when this became available, or when it arrived on the Australia Station in ships which had been constructed in the UK. To these was added American radars, in particular the ubiquitous SG ‘Sugar George’ surface warning radar. By the war’s end, there were few RAN vessels of any kind without radar, including the Fairmile motor launches. The best equipped were the cruisers and destroyers, as the following examples demonstrate:

Australia	A286. 960. 273, 281, 282, 284, 285
Shropshire	273. 277Q. 281. 282. 283. 284. 285. SG.
Adelaide	271. A290. SC.
Hobart	273, 276. 277Q. 281AEW. 282, 284 285, SG.
Tribal Class destroyers	285. A286. 293. 974. SC. SG.
N Class Destroyers	271. 285, A286. 291. SG.
Q Class Destroyers	262. 277. 285, A286. 293.
Bathurst Class Corvettes	A272. 276. A286

World War 2 Wireless & Radio Mechanics

In September 1939, just as the RAN had no radar, it had no personnel trained in the operation and maintenance of the equipment. Traditionally the RAN had Engineering, Gunnery, Navigation, Communications, Supply, Electrical and Medical branches. Within the Communications branch the Telegraphists' main role was to operate the wireless telegraphy equipment. Their subsidiary role was to maintain the equipment which, in the immediate pre-war days, was fairly simple.

As radar began to appear in ships, the need was recognised for personnel skilled in getting the most benefit out of the new sensor system and in installing it and keeping it operating. The RAN found both tasks a difficult challenge. This article looks only at the problem of enlisting and training of personnel for the maintenance function.

In March 1941, the Engineer Officer of HMAS *Perth*, then heavily engaged in fighting in the Mediterranean, appealed for a specialist in radar maintenance to

be posted to the ship to keep its British Type 286 operating.[17] By that time, it had become clear that the maintenance responsibilities of the Telegraphist could not be extended to the more advanced electronics involved in radar. To address this need, the new RAN category of Wireless Mechanic was conceived late in 1941, and introduced to the RAN early in 1942.[18]

To create the new Wireless Mechanics, selected personnel were to be given a basic training course of six months duration at the Melbourne Technical College, later known as the Royal Melbourne Institute of Technology (RMIT) on the principles of electronics. This was followed by equipment training at the RAN shore establishments of HMAS *Rushcutter* and HMAS *Watson* in Sydney, and at HMAS *Harman* and the Belconnen transmitting station, both in Canberra. A few of the selected personnel came from existing naval ranks, but the majority was recruited from civilian life. Typically, the recruits were in their early 20s, and had secondary school education to Year 5 level. Good passes in mathematics and physics were preferred. There were exceptions, even for older recruits with a strong background in radio.

The task of the new Wireless Mechanic was to install and to maintain wireless equipment, but particularly the new radars. However, as the title ‘Wireless Mechanic’ no longer completely described their responsibilities, in 1943 the maintainers' title was changed to ‘Radio Mechanic’ (RM) and the new specialists became responsible for the satisfactory performance of all electronic equipment in their ships.[19] Thus, within the space of twelve months intensive training these Hostilities Only Radio Mechanics (HORMs) had graduated to having the responsibility of keeping all of a warship's radar and communication equipment fully functional.[20]

What happened subsequent to the basic training depended upon two factors. One was the instructors' assessment of each student's potential, and the other was the manpower needs of the Navy. Most graduates were very keen to be given the training which would lead them to a sea going ship. However, there were a number of shore based manning requirements, such as the Naval Transmitting Station at Belconnen Canberra, HMAS *Melville* in Darwin, and HMAS *Magnetic* in Townsville. As well, the advanced training in radar was carried out at HMAS *Rushcutter*, and later at HMAS *Watson* when that establishment was commissioned. So quite a few RMs missed the glamour and excitement of being on the front line with the enemy. It is estimated that 363 men qualified as RMs in the period January 1942 through August 1945.[21] HORMs were assigned to 194 ships and shore establishments between 1942 and the end of 1945, of which122 were sea going vessels.

In early 1945, the RAN recognised that with the imminent cessation of hostilities, most of the Hostilities Only (HO) sailors would be demobilised, potentially leaving the essential services they maintained unmanned. To address this eventuality, a recruiting program of 12 years continuous service was introduced later in 1945 for all branches of the service. An estimate of the number of RMs necessary to man the post war Navy, showed how critical the situation was deemed to be, with an estimate of just 5 serving members who would transfer to the permanent forces, leaving a shortage of 152. [22] The schedule indicated that 101 of these 157 RMs would be destined to serve in the 54 naval vessels in commission at the time, 33 would serve in shore establishments and there would be a ‘pool’ of 14. The Director of Technical Staff Requirements subsequently revised this estimate upwards to 285.

However, eight months later on 25 April 1946, the CO of HMAS *Watson*, Commander Neil McKinnon, proposed a total of 171 RMs to man 36 ships and 11 shore establishments. This program called for a selective recruitment to induct fifteen classes at the rate of eight classes per year. Class duration was to be 39 weeks: in fact it became 49 weeks.[23] Following recruit training at HMAS *Cerberus*, trainee RMs spent six months based at the shore establishment HMAS *Torrens*, Port Adelaide. Daily they would be transported to the then School of Mines, later to be absorbed into the University of South Australia, for basic training in electrical and electronic theory and practice. Graduates were then sent to HMAS *Watson* for training in Radar or W/T equipment, according to the manning needs at the time. It was considered to be too onerous to expect the students to learn all of the W/T and Radar equipment at the time. So there was initial specialisation in W/T or Radar, with cross training a year or so later.[24]

The first class commenced training at the School of Mines in January 1946, and the last completed the initial training in April 1949. During this forty month period, approximately 180 RMs graduated from the School of Mines training program. Commander McKinnon's crystal gazing 3 years previously proved to be remarkably accurate. Subsequently, the Radio Mechanic branch was folded in to the Electrical branch, and different conditions were introduced to meet the changing needs of the service. [25]

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[1] Acker, Arnold E., *Basic Fundamentals and Applications of Radar*, Palo Alto Ca.: Varian Associates, 1966, Foreword
[2] Ibid. **[Page no?]**
[3] Pope, Dudley, *The Battle of the River Plate*, London: William Kimber, 1956, P.49
[4] *Radar at Sea*, **[need full details and page no.]**
[5] Ibid**, [ditto]**
[6] NAA MP1049/5, Item 2027/7/221 – RDF Types 271-2-3, Range Scales.
[7] Watson, P.R.H., *'It's Nothing to Do with Me: I'm Radar'*, *A Further Slant on the RAN Radio Mechanic History*, Melbourne: The Craftman Press, 1998, P. 2.
[8] NAA ??????, Letter by Engineer Captain A.C.W. Meares to Navy Office Melbourne of 26 May 1939.
[9] Watson, *'It's Nothing to Do with Me'*, P.5.
[10] Ibid, P.6.
[11] NAA MP1049/5, Item 2037/8/364 – Radar Equipment for RAN, Radiophysics Laboratory letter GCFW/JDS of 14 January 1942.
[12] Watson, *'It's Nothing to Do with Me'*, P. 8.
[13] **[*Kybra* trials reference]**
[14] A272, A276 Comparison by PO RM, in possession of author
[15] Watson, *'It's Nothing to Do with Me'*, P.75.
[16] NAA MP 1049/5, Item 2037/7/256 – RDF: Report on RN, USN and RAN Policy, report dated 24 December 1942.
[17] NAA MP150/1, Item 589/201/859 – HMAS PERTH – Electrical Report for ½ Year ending 31/03/41.
[18] Commonwealth Navy Order 194/42
[19] Commonwealth Navy Order 414/43.
[20] Stevens, George, *Royal Australian Navy Radio Mechanics: The HORMs 1942-1945*, Sydney: Self-published, 2005.
[21] Stevens, *The HORMs*, P. 94.
[22] NAA ??????, DTSR minute dated 13 August 1945 **[Need NAA series and item numbers]**
[23] Stevens, George, *Royal Australian Navy Radio mechanics: A History of the Torrens Era*, Sydney: Self-published, 200, P. iii.
[24] Ibid, P. iv.
[25] Ibid, PP 1-7.

Radar Officers

While a program was in hand to generate the personnel to install and maintain radar equipment in ships, the RAN also recognised the need for officers to lead the new branch. Much of the work they were called upon to do was new and experimental.
The following is an account of the experiences of the first officer recruited specifically for this purpose, Lieutenant (SP) David Medley RANVR.[26]

I was the first officer recruited directly into the RANVR for RDF duties on 1 November 1941. This was in response to an ad which appeared in the Melbourne papers around September 1941. At that time I was the only one recruited and I suppose probably the only applicant at that time. I was transferred to the Admiral's staff in Sydney where I was assigned to the Flag Lieutenant, Lieutenant Commander John Bath. Also on this staff was a Warrant Officer by the name of Jock Smart. Jock was a Telegraphist and had been assigned for RDF duties. He knew very little about RDF and was happy to have me aboard. Little did he know that I knew nothing about it either but I did have a Masters Degree in Physics, had been a ham radio operator for some years, and interested in electronics as far back as I could remember. This deficiency was soon rectified as I was given a crash course at the Radio Physics laboratory and access to all the classified material the RAN had at that time, which I absorbed like a sponge. After a sojourn at Flinders where I was supposed to learn how to be an officer, I was assigned to help with the RDF installations on Canberra*, presently refitting at Garden Island. On completion of this work early in 1942 I was assigned to her as RDF Officer. Subsequent events were recorded in 'The Shame of Savo', so I will not repeat them here.*[27]

I have only the haziest recollection of the 'Bailey Boys' [see below] *as I never had anything to do with the training school at HMAS* Watson*. I do recall that after I returned from the Savo affair, four RAAF officers and four RAAF mechanics were loaned by the RAAF to assist in the training of RDF operators. Also about this time (late 1942), a distinguished A/S officer, Lt Tom Cree DSO, returned from Europe and was assigned OIC of the RDF section in Navy Office Melbourne, and I essentially worked for him for the remainder of my stay in the Navy.*

Even at this time I was the only officer with a firm technical background and I suppose I was regarded as something of a 'Whiz Kid'. In any event I was frequently called upon to work on installations which had been beyond the capabilities of the personnel concerned. I remember working on the RDF installation on Queen Mary *while she was in Sydney. I remember working all night on an obscure fault in a gunnery control Radar on* Warramunga*, and I remember being sent to service RDF equipment on board a royal Dutch cruiser called* Van Tromp *[HNlMS* Tromp*] in New Guinea. I remember vividly a spell in Brisbane with a US Navy submarine tender which was installing gunnery control Radars on* Australia *and* Hobart*. I was the liaison between the RAN and USN and I can recall that this was a fun time, and I learned a lot more about Radar from a Westinghouse Field Engineer who was supervising these installations.*

I remember being sent to the USN PT boat bases on Guadalcanal and Savo Island sometime in 1943 to learn as much as I could about the SO Radars which the RAN had purchased for installation in the Fairmiles. These were subsequently installed at Rushcutter *and I would suppose I supervised at least the first several installations. My most vivid recollections of this period were an overnight stay with a bunch of Coast Watchers who were waiting to be picked up*

[26] Letter written 19 September 1995 by Lt (Sp) David Medley RANVR to John Saywell OAM, President of the RAN Radio Mechanics Association
[27] Loxton, *The Shame of Savo*, PP 65and 260

by a submarine and deposited behind enemy lines and a ride on a PT boat from Guadalcanal to Savo.

As to the laboratory, I was nominally in charge of it while it was at Rushcutter *from the time I returned from* Canberra *until I left the Navy in late 1945. I say nominally because I was away on special assignments a great deal of the time. On the other hand Alan Young was there all the time and will remember a lot more detail than I. The functions of the lab were as far as I can recall:*

1. To provide a test facility for acceptance testing of Radar equipment being built in Australia.
2. To maintain a set of accurately calibrated test instruments, which could be used to maintain standards of accuracy at RAN service bases.
3. To test new Radar equipment from overseas and to become familiar with it before it was installed in ships.
4. To develop new ideas as appropriate. In this area I worked on a Doppler radar idea which has just now become a hot topic here in the USA. I also worked on Radar jamming equipment in the latter part of the war.

In 1945 it was decided to transfer the lab to Watson*, and Alan and I designed a building for it. Whether this was ever built I am not sure but I do know the lab was never transferred to* Watson*, but was reinstalled out at the Navy Stores facility at Leichhardt sometime in 1945 – 46.*

The Bailey Boys[28]

In 1941, the Department of Physics, University of Sydney was selected to train men in the science of Radio Location, The major thrust for this was through the Royal Australian Air Force but the Royal Australian Navy also participated in this program to a lesser degree. The man charged with the responsibility of developing and delivering the lengthy and high pressure training course was Professor Victor A Bailey, University of Sydney. A natural consequence was that Victor Bailey's charges came to be known as, The Bailey Boys.

The first intake, mainly, but not all, second year undergraduates of Sydney University, commenced their training on the 15th September 1941, concluding in February 1942. The second course commenced in March 1942 with undergraduates from five Australian universities. In this class were fifteen RAN trainees, the only RAN officers to be trained in the Bailey Boy program. Fourteen of the initial fifteen successfully completed the University of Sydney training. They were then sent to Flinders Naval Depot for 6 weeks officer training, followed by a period at what was to become HMAS *Watson* at Sydney's South Head. At South Head they familiarised themselves with contemporary radar equipment, and were then each sent to different ships and shore establishments for operational duties.

The accent was on understanding the basics of the technology by a thorough examination of the underlying mathematics and physics, supplemented where appropriate by exercises. Some of the topics included analyses of complex circuits using differential equations and a vector approach to the steady state, and the use of operators and complex numbers.. There were lectures on topics such as thermionic valves, cavity resonators, types of oscillators, amplifiers, phase inverters and harmonic resonators. As well students studied metalwork, woodwork, the use of equipment and safety considerations. Wave form

[28] Historical Records of Australian Science, 'The Bailey Boys' by Walter Fielder-Gill; 'Radar at Sydney' by Robert Slatyer; an address given by Bob Slatyer at the Bailey Boys 50th anniversary Reunion September 1994; and biographical notes compiled by John Medhurst.

generation and propagation received a lot of attention. Throughout, there were 34 major exercises to be completed, regular tutorials, and periodic one hour examinations.

The desired outcome of this intensive training program was to create a cadre of technical officers who would be capable of assuming lead roles in the design, development, installation, and on occasions the repair of obscure operational faults, of radar technology. As well, these men would be required to devise radar counter measures, to assist in the creation of maintenance handbooks for the various radar models being produced, to liaise with contractors and civilian manufacturers, to be the administrators of radar installations and to be the mentors of the maintenance technicians. All this after an incredibly short period of about 12 months training. Considering that all were second year university undergraduates aged around 19 upon commencement of their training, the desired outcome became a remarkable success.

RAN Bailey Boys served in the HMA Ships *Australia*, *Shropshire*, *Hobart*, *Manoora*, *Bataan*, *Yandra*, *Kanimbla*, *Westralia*, *Kybra, Townsville*, and S*wan*. As well as these shipboard responsibilities, Bailey Boys had different assignments as Port Radio Officers, Dockyard Officers, Instructors, Installation Officers, Radar Counter Measure Officers. They served in various Papua New Guinea east coast locations such as Madang, Lae, Aitape. As well they were on the New Guinea west coast, and further north and west of what is in 2004, Irian Jaya, into the Indonesian islands of Sulawesi and the Halmaheras. In terms of wide ranging operational locations, the cream on the cake, so to speak, was that two were in Tokyo Bay for the Japanese surrender.

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Radar Equipment HMAS *Shropshire*

As the Pacific War progressed, more and more RAN ships were progressively fitted with radars of various kinds, from British, Australian and US sources. The peak of the state of the art, as it was in those days, was achieved in HMAS *Shropshire*, a County Class heavy cruiser transferred to the RAN by the RN to replace her sister ship, *Canberra*, lost as a result of the Battle of Savo Island on 9 August 1942. The following description of her radar outfit has been provided by Lieutenant (SP) R. Slatyer RANVR. Radar Technical Officer, HMAS *Shropshire* from October 1943 to January 1946.

When Shropshire was being prepared in England for handing over to the RAN in 1942/43, she was fitted out with a full complement of the current R.N. equipment. The following list of equipment in numerical order of type number includes other equipment installed later.

- *Type 273 - Surface Warning. Wavelength 10 cm, frequency 3,000 MHz. Located just forward of the after control position. Antenna gyrostabilised, located in a 'lantern" structure directly on top of office. Also connected to an accurate range display panel in the T.S. [Gunnery Direction Transmitting Station]*
- *Type 277 - Aircraft Tracking. Wavelength 10 cm, fitted during a refit in mid 1945. Antenna on foremast. Office in new extension on port side of bridge structure. Single 'dish' antenna controlled for both elevation and bearing, enabling this equipment to provide information on the exact location of an aircraft.*
- *Type 281 - Air Warning. Frequency 90 MHz. Transmitting antenna on mainmast with transmitter in office at base of the mast. Receiving antenna on foremast with receiving office on flag deck at base of mast. Antennas rotated in synchronism. The 281 was undoubtedly* Shropshire's *most important radar unit! More on this later.*

- *Type 282 – Fire Control. For control of multiple pom poms, one set for port and one for starboard.*
- *Type 283 - Auto Barrage Unit. One for each turret. Each set had a control station with display unit on the upper deck. Main office below decks. The purpose of these sets was to enable efficient use of the main armament against dive bombers. We found them quite useful when there were kamikazes around.*

  Each of these sets was equipped with a small fire control device – a sort of mechanical computer. When the main armament guns were loaded with shells fitted with a time fuse, generally set for a different time in each barrel, this device would calculate the correct time and fire the gun so that the point at which the shell exploded was the point at which the aircraft would be if it continued on the same course and speed.
- *Type 284 - Gunnery Control Main Armament. Antenna mounted on the main armament director. Office below decks, accurate range display panel in the TS provided range and bearing for main armament fire control.*
- *Type 285 – 4-inch Anti-aircraft Guns. Antenna mounted on after director – high angle control position. Office below decks. Provided range and bearing for anti-aircraft fire control.*

Power supplies to all of the gunnery control radars were combined in an integrated system. All sets operated at the same frequency, around 600 MHz. Power was supplied from a large motor alternator set with output 180 volts at 500 cycles, which was their pulse repetition frequency, and interference was avoided by having a phase difference between the power supplied to each set.

- *Type SG - Surface Warning. An American unit of 10 cm wavelength fitted soon after we joined the 7th Fleet. Antenna on foremast, PPI display in plot below bridge. Used for surface navigation as well as surface warning.*
- *Radar Countermeasures. Equipment consisted of multi-band receivers and a Type 91 jamming transmitter.*

Capability Report

During service in the New Guinea and Philippines campaigns HMAS Shropshire *achieved a reputation for, among other things, the efficiency of reporting aircraft movements.*[29] I *will attempt to explain, briefly, how I consider this was achieved.*

This efficiency was due to a combination of:
- *The nature of the equipment*
- *Maintenance and tuning*
- *Skill of the operators*
- *Efficiency of the plotting office*
- *Team work*

Nature of the Equipment. The primary air warning radar was Type 281. This was a rugged piece of equipment built in the style of the RN. long range W/T sets. The output stage of the transmitter gave an impression of power with quartz 'tubes' about 12 cm in diameter and 40 cm long. The antennas were broadside-style arrays, with timber frame, ceramic insulators, and aluminium dipoles. The feeder for the transmitter was of twin wires held apart by plastic insulators. The receiver feeder was 'Pyrotenax'. The receiving office was on the flag deck at the

[29] Nicholls , *HMAS* Shropshire, PP. 182-3 cited a number of high commendatory remarks about *Shropshire's* radar efficiency, made by senior officers of the USN, & RN.

base of the foremast. In this were all components of the receiver, including the display and the controller for rotation of the antennas as well as the telephones.

Maintenance and Tuning. Because of wartime shortages in England, the materials used for the construction of exposed parts were not always as durable as they could have been. This factor, added to the severity of the tropical conditions in which we were operating, resulted in the need for frequent maintenance work to maintain peak performance. Careful attention was given to this, which included much masthead work, varnishing woodwork and cleaning insulators – even on one occasion, at night in the tail end of a typhoon, to wash off salt spray which was causing sparking while the ship was darkened. As regards tuning, one feature of the 281 was that most units where tuning was critical were designed so that they could be tuned to maximise performance. This is different from many other radars, where such units are preset and changes over time can adversely affect performance.

Skill of the Operators. The display was a cathode ray tube about 15 cm in diameter, known as an 'A' scan. The operator had control of the rotation of the antennas, which rotated in synchronism, and he would adjust the angle of the antennas relative to the fore and aft line of the ship to maximise the 'pip' and to find the bearing of the aircraft. Some refinements in technique would provide an estimate of the height of the aircraft.

This information would be telephoned to the Plotting Office. To accurately maintain reports on a number of aircraft on this type of equipment required a great deal of skill on the part of the operator. There would be two operators on watch and they would relieve each other from time to time. Shropshire *was fortunate in having a number of men with this ability.*

Efficiency of the Plotting Office. As well as receiving the reports of aircraft detected by the ship's radar, this office was in communication with other ships in the fleet, friendly aircraft and shore bases. Reports of aircraft positions were plotted on a large board. At times, a great deal of information was processed and personnel became very skilled. The officer in charge was of a temperament well suited to his position. Shropshire's [radio] *callsign was 'PORTHOLE' and this name became famous as a source of information on warnings of hostile aircraft.*

Teamwork. As with all operations in a fighting ship, the overall efficiency depended on team work. In Shropshire *there had been very few changes in personnel, and all members of the ship's company had learnt to work together. This undoubtedly was an important factor in all operations. Perhaps the reports that she was a 'Lucky Ship' also had some validity.*

Conclusions

The outbreak of World War Two found the RAN without any radar and with scant knowledge of this important new technology. Early interest in radar at a technical level was encouraged and supported by the Australian Government, and an organisation created to provide this country with a significant element of self-sufficiency in radar development and production.

For the RAN, the arrival of radar created demands for personnel to operate it and to maintain it. Traditional arrangements and responsibilities needed to be overhauled and a new branch – Radio Mechanics and officers to lead it – created from scratch. Even with the restrictions caused by Britain's own preoccupations and material demands, by 1942 the RAN not only had radar in many ships, but had developed the capability to support it. Given the huge number of competing demands on men and material, this was a significant achievement, for which

much credit must go to the foresightedness of a few key officers and the dedication on the new HORMs and their officers.